

MEMBRANE HYBRID SYSTEM IN HIGH QUALITY WATER REUSE



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A Thesis submitted in fulfillment of the requirements for the
degree of Doctoral of Philosophy

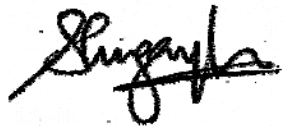
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I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

A handwritten signature in black ink, appearing to read 'Sukanyah', is written over a horizontal dotted line.

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15th June 2015

JOURNALS AND CONFERENCE PAPERS PRODUCED FROM THIS STUDY

Sukanyah Shanmuganathan, Tien Vinh Nguyen, Sanghyun Jeong, Jaya Kandasamy, Saravanamuthu Vigneswaran Submerged membrane – (GAC) adsorption hybrid system in reverse osmosis concentrate treatment. *Separation and Purification Technology*, 146 (2015) 8–14

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ABSTRACT

Although membrane filtration treatment for water reclamation is becoming more widespread, the challenges such as membrane fouling, high cost, management of concentrate, and incomplete removal of organic micro pollutants still prevail. This study presents technical alterations to minimize such issues via the development of pre-treatments techniques where fluidized bed contactors and membrane hybrid systems were used. Granular activated carbon (GAC) and an ion exchange resin (Purolite A502PS) were used as adsorbents for the above mentioned pre-treatments respectively. Biologically treated sewage effluent (BTSE) collected from a water reclamation plant, Sydney was used as a feed water for these experiments. The operational conditions such as fluidization velocity and adsorbent dosage of fluidized bed columns strongly influenced the removal of dissolved organics (DOC). GAC was found to be more effective in removing organics compared to Purolite A502PS. This could be due to the competition provided by other inorganic anions present in BTSE for Purolite exchange sites. Plug flow model was successfully used to predict the impact of the amount of adsorbent and of the flow rate on the removal of organic matter.

A similar trend was observed when another pre-treatment technology of membrane hybrid system was used. Micro filtration (MF) – GAC hybrid system effectively removed hydrophobic organics, hydrophilic organics and organic micro pollutants, whilst, the removal of inorganic ions was minimum. Comparatively, the performance of MF-Purolite hybrid system was less efficient in DOC removal; however the removal of sulfate and nitrate ions was good. In both membrane hybrid systems, the addition of adsorbents directly into the membrane reactor reduced membrane fouling by membrane surface scouring and adsorption. Overall, the performance of membrane-GAC adsorption hybrid system was more effective than membrane-ion exchange hybrid

system. Based on this, MF-GAC was suggested to combine with nano filtration (NF) system. Here second membrane filtration of NF was to further polish pre-treated BTSE in terms of dissolved organics, organic micro pollutants and for some divalent ions removal. This treatment system is referred as 'dual membrane hybrid system' i.e., the combination of MF-GAC adsorption hybrid system followed by NF. Traditionally RO is used as a polishing step in dual membrane systems in waste water reclamation plants. The use of NF instead of RO is found to be cost effective in terms of energy requirements. This dual membrane hybrid system is suggested to produce high quality water reuse where the removal of monovalent ions is not necessary; however the selection of treatment system depends on the requirements of recycled water for end purposes. For example, the recycled water used for irrigation requires sodium adsorption ratio of 3-9 for wide range of salt tolerant crops. Therefore, a study was conducted to determine whether the BTSE can be treated using nanofiltration (NF) and reverse osmosis (RO) to bring these risk parameters within safety limits, because the NF treated BTSE could bring SAR levels only up to 14. As per the results, it was suggested to blend NF and RO permeate in equal proportions to produce a product quality suitable for irrigation with SAR value below 10. Utilizing NF prior to RO reduced the RO membrane fouling and both NF and RO removed most of the organic micro pollutants from BTSE and this may subsequently protect soil and ground water from potential hazards.

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ABBREVIATIONS

AC	Activated carbon
AER	Anion exchange resin
ANZECC	Australian and New Zealand Environment and Conservation Council
AOC	Assimilable organic carbon
ATP	Adenosine tri phosphate
BAC	Biological activated carbon
BOD	Biological oxygen demand
BTSE	Biologically treated sewage effluent
CEC	Critical Environmental concentrations
CFU	Colony forming unit
CMF	Continuous micro filtration
COD	Chemical oxygen demand
DBPs	Disinfection by products
DOC	Dissolved organic carbon
EC	Electric conductivity
EDCs	Endocrine disrupting compounds
EfOM	Effluent organic matter
EPA	Environmental protection agency
F-EEM	Fluorescence excitation emission matrices
FTIR	Fourier transform infrared spectroscopy
GAC	Granular activated carbon
HA	Humic acid
HRT	Hydraulic retention time
HSDM	Homogenous surface diffusion models
IER	Ion exchange resin
IMS	Integrated membrane systems
LC-OCD	Liquid chromatography organic carbon detection
LMW	Low molecular weight
LPRO	Low pressure reverse osmosis
MBR	Membrane bio reactor
MCC	Membrane correlation coefficient
MF	Micro filtration
MIEX	Magnetic ion exchange
MSFD	Multi-stage flash distiller
MW	Molecular weight
MWCO	Molecular weight cutoff
NF	Nano filtration
NOM	Natural organic matter
NSAIDs	Non-steroidal anti-inflammatory drugs
PAC	Powdered activated carbon
PhAC	Pharmaceutically active compounds

PPCPs	Pharmaceuticals and personal care products
RO	Reverse osmosis
ROC	Reverse osmosis concentrate
SAR	Sodium adsorption rate
SDI	Silt density index
SEM	Scanning electron microscope
SMPs	Soluble microbial products
SWRO	Sea water reverse osmosis
TDS	Total dissolved solids
TMP	Transmembrane pressure
TOC	Total organic carbon
TSS	Total suspended solids
UF	Ultra filtration
VOCs	Volatile organic compounds
WHO	World health organization
WRP	Water reclamation plant
WWTP	Wastewater treatment plant